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COMPOSITION OF MILK
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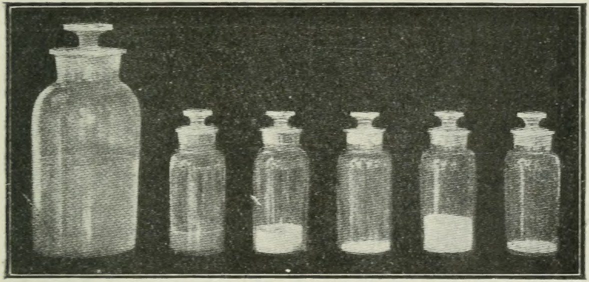

FIG. 61.—*The constituents of a quart of milk*

Water	Fat	Casein	Albumen	Sugar	Ash
87%	4%	2.6%	·7%	5%	·7%
29.93 oz.	1.38 oz.	.89 oz.	.24 oz.	1.72 oz.	.24 oz.

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COMPOSITION OF MILK AND SOME OF ITS PRODUCTS

H. E. Ross.

Milk is one of our most important foods. Since its food value depends to a considerable extent on its composition, a knowledge of its composition is desirable for every one.

The colour of milk is yellowish white, a colour somewhat difficult to describe accurately. It is so characteristic of milk that we often refer to the colour of certain objects as "milk white," thus giving to milk a distinctive colour of its own. This peculiar colour is due to a substance called lactochrome.

The taste and odour of milk are sweetish, although pure milk has little of either. If there are strong flavours and odours they are due to the food eaten by the animal or to contamination of one kind or another, such as may result from dirty stables or unclean utensils.

Freshly drawn milk has a double, or amphoteric, reaction. It acts as an acid on an alkali and as an alkali on an acid, turning blue litmus paper red and red litmus paper blue. After standing for a time the reaction usually becomes decidedly acid, due to the action of lactic-acid bacteria. These bacteria, or germs, work on the milk sugar and convert it into lactic acid.

When milk is boiled in an open vessel a heavy scum of dried milk forms on the surface. If this scum is removed another will appear as soon as the milk is boiled, and such a membrane will form as long as any milk is left. If milk is boiled in a closed vessel the scum does not form.

For all ordinary purposes milk may be said to have six constituents, which, together with the percentage of each, are as follows :—

	Percentage.
Water	87.0
Sugar	5.0
Fat	4.0
Casein	2.6
Albumen	.7
Ash	.7

For many reasons, some of which are not well understood, the composition of milk is variable. The physical condition of the cow, the kind of food given, the housing, and the age of the cow are four things that may affect the composition. Wing, quoting from Koenig, gives the following variation of normal milk :—

	Percentage.	
	Maximum	Minimum.
Water	90.69	80.32
Sugar	6.03	2.11
Fat	6.47	1.67
Casein	4.23	1.79
Albumen	1.44	.25
Ash	1.21	.35

Of course, single variations may be found that go either above or below the limits given in the table ; but the figures presented are the results of a large number of analyses of samples of normal milk.

For purposes of convenience the content of milk is grouped in several divisions, as represented in the following table :—

	Water			Fat	
Total solids	Fat		Milk serum, or skimmed milk	Water	Whey
	Sugar	Solids not fat		Sugar	
	Casein			Albumen	
	Albumen			Casein	
	Ash			Ash	

There is a small amount of ash in whey also, and this is the part that is soluble.

The density of milk is greater than that of water, the specific gravity of normal milk being 1.029 to 1.034, with an average of 1.032. The specific gravity of milk is affected by variation in the milk solids. The New York State laws require that milk must contain not less than 11.5 per cent. of total solids, of which at least 3 per cent. shall be fat.

One quart of milk weighs 2.5 pounds. While milk is variable in composition, the variation is not enough to make a great difference in the weight of one quart. This factor, 2.5, is the one used in changing quarts to pounds or pounds to quarts.

COLOSTRUM

The milk secreted by the cow a few days before and a few days after the birth of a calf is called colostrum, or beestings. It differs in appearance and composition from normal milk and its composition is variable. Usually, colostrum is low in sugar and fat, and high in albumen and ash. The following table, taken from Fleischman, gives the average composition and the maximum and minimum variation of colostrum :—

	Percentage.		
	Average composition.	Maximum variation.	Minimum variation.
Water ..	71.69	70.60	67.43
Fat	3.37	4.68	1.88
Casein ..	4.83	7.14	2.64
Albumen ..	15.85	20.21	11.18
Sugar ..	2.48	3.83	1.34
Ash	1.78	2.31	1.18

It is highly desirable that the young calf receive the colostrum, for this food acts as a purgative and a stimulant to the digestive system of the young animal.

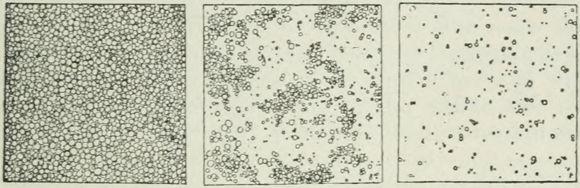
Colostrum is not considered fit for human consumption. Previous to the secretion of colostrum the udder has usually been in a state of inactivity, and just before or just after the birth of the calf it suddenly becomes very active. This sudden activity may result in more or less inflammation ; and whenever there are inflammatory conditions, poisons that may be harmful to the human system are likely to be given off. The New York State dairy laws regard colostrum as one form of adulterated milk, and prohibit the sale of milk from a cow either fifteen days before or five days after calving.

By referring to the above table showing the composition of colostrum, it will be noted that there is a high percentage of albumen. Since heat readily coagulates albumen, boiling the milk is used as a tést to determine when it has passed from the colostrum to the normal stage. Because of its high albumen content, colostrum thickens at once when boiled. Normal milk does not thicken when boiled.

CONSTITUENTS OF MILK

Milk fat.

Fat is one of the most important constituents of milk. As a food milk is better if it contains a fair percentage of fat than if this percentage is small. For manufacturing purposes, milk fat is very important. One of the best illustrations of this is in the manufacture of butter, which is largely fat. Also, more cheese can be made from one hundred pounds of milk rich in fat than from the same quantity of milk with low fat content. The amount of fat in milk is so important that milk is frequently bought on the fat basis. The percentage of fat in milk is usually determined by the Babcock test.



Cream Milk Skimmed Milk

FIG 62.—*The appearance of cream, milk, and skimmed milk when examined through a high-power microscope. The round bodies are fat globules that float in the serum, or watery part of the milk.*

Fat exists in milk in the form of small droplets or globules, forming an emulsion—that is, a liquid with the fat in a state of fine suspension ; the fat is not in solution.

This condition is favourable for digestion. Each globule is spherical in form and it keeps this form by reason of its power to condense about it the liquid part of the milk.

The fat globules are very tiny, being about 1/1,500 to 1/25,000 of an inch in diameter. A high-power microscope is required in order that they may be seen, and some idea of their minuteness may be obtained when it is stated that in one cubic centimetre of milk (about 22 drops) there are one to two billion fat globules.

The fat is lighter than the other constituents of milk and when milk is allowed to stand the fat globules rise to the surface, forming what is called a " cream line." This layer of cream can usually be seen distinct from the rest of the milk. The presence of a thick cream line indicates that the milk is rich in fat. The absence of a cream line is not, however, a positive proof that there is a small percentage of fat in the milk, although it indicates that such is the case. The writer has sometimes found milk testing 4.2 per cent. fat which showed almost no cream line. Just why the fat does not always rise readily is not fully understood.

Milk fat is not one fat alone, but is made up of about nine different fats. These all have different properties, and the character of the butter is influenced by the kinds of fat of which it is composed. One of the fats in milk is called " olein," and another is called " stearin." Olein has a melting-point of about 43° F. and stearin a melting-point of about 143° F. The melting-points of the other fats lie between these limits. The melting-point of butter is therefore variable according to the amount of the different fats present, and is between 92° and 96° F. One of the fats in milk, called " butyrin," is the characteristic fat of butter, because it imparts the flavour and odour that are recognised as butter flavour and butter odour.

All the fats in milk fat have the same basis, which is glycerine. They are formed by the union of glycerine with the corresponding fatty acid. For example, butyrin is made up of glycerin and butyric acid ; olein is composed of glycerine and oloeic acid. Nearly every one has had experience with strong or rancid butter. Such rancidity is due to the splitting up of butyrin into butyric acid and glycerine. The butyric acid produces the strong, disagreeable flavour and odour. It is a strange fact that no chemist can make in the laboratory any of the fats of milk fat. The cow alone can do this. A chemist might be given glycerine and butyric acid, with all laboratory facilities, but he could not make butyrin.

Fat is the most variable constituent of milk. There are several conditions under which it varies, the reasons being not always understood. Some of the reasons are as follows :—

1. Variation due to breed. This fact is well known, and needs no discussion.

2. Variation due to age of the cow. As the cow grows older, the percentage of fat decreases.

3. Variation due to physical condition of the cow—whether she is sick or well. It cannot be predicted whether the percentage of fat will increase or decrease.

4. Variation due to period of lactation. The percentage of fat increases as the period of lactation advances.

5. Variation between animals of the same breed. This is to be expected, since individuals always vary.

6. Variation in different parts of the udder. The first milk drawn is very poor in fat, and the last milk drawn is very rich in fat. Often there will be a variation of 1 to 9 per cent. between the first and the last milk.

Milk fat compares well with other fats in digestibility.

Casein.

Casein, popularly called "curd," exists in milk in a colloidal state, that is, in a state of very fine suspension. The particles of casein are in much finer suspension in milk than are the fat globules ; the fat globules may be seen with the high-power microscope, but the casein cannot be seen at all. Casein is held in suspension by calcium salts, and when anything forms in milk or is added to it which unites with the calcium salts, the casein is thrown down. This is what happens when milk sours naturally. Acid forms in the milk, uniting with the calcium salts, and the casein comes down in a mass.

Casein forms a considerable part of the various kinds of cheese. American cheddar cheese is about one-third casein. In either milk or cheese, casein is a very excellent food. It is high in nitrogen content ; and this is one reason why whole milk and skimmed milk are excellent foods for growing animals.

Milk casein has many important commercial uses. It is used to finish writing-paper, much of our finest stationery being finished with it. It is used as a substitute for bone and celluloid in the manufacture of buttons, backs of brushes and combs, and many toilet articles, and is employed as a basis in the manufacture of cold-water paints and of glue.

Milk Sugar.

Milk contains about 5 per cent. sugar, and this percentage is fairly constant. The sugar is in solution ;

it is not quite so soluble as ordinary cane sugar, and not so sweet. Milk sugar is used commercially in the manufacture of proprietary foods, and in pharmacy for coating pills and making powders. The manufacture of milk sugar is an expensive process, and is carried on only where large quantities of skimmed milk or whey are available.

Milk sugar is of great importance in dairy manufacturing because the acid in milk and cream is produced from it, and we have come to like dairy products the flavour of which is affected by the formation of this acid. The public demands a butter made from cream soured with lactic acid. In the manufacture of American cheddar cheese the amount of acid formed at different stages in the process of manufacture greatly affects the kind and quality of the product.

Lactic acid, as found in milk, is made by the action of lactic-acid bacteria on milk sugar. These bacteria, or germs, are found nearly everywhere in external nature, and occur on the body of the cow, on the dust in the air, and on the clothing of the milker. Unless precautions are taken, these germs get into the milk, and under conditions favourable to them they multiply rapidly and cause the milk to sour. The chemical reaction that takes place is given as follows :—

$$\text{Milk sugar} = \text{lactic acid.}$$

$$C_{12}H_{22}O_{11}.H_2O = 4C_3H_6O_3$$

Milk sugar is found nowhere in nature except in the milk of animals of the class known as Mammalia.

Albumen.

Albumen is a nitrogenous substance in solution in milk ; being in solution, it is easily digestible. In composition it may be compared to the white of egg. It is precipitated by heating to about 160° to 170° F., and when once thrown down it will not go into solution again. The fact that albumen is precipitated by heat is the reason why milk utensils, when cleaned, should be first rinsed in cold water. If hot water is used first, the albumen is precipitated on the utensil, and, being sticky, is difficult to remove. If there are cracks or seams in the utensil some of the precipitated albumen lodges in these ; and since albumen is an excellent food for bacteria the utensil soon becomes a source of contamination for all milk that comes in contact with it.

Albumen has one commercial use—in the manufacture of Italian cheese. This cheese is made where large quantities of whey are obtainable. The whey is heated to a high temperature which precipitates the albumen. The albumen is allowed to collect, the whey is then drawn off, and the albumen is drained and dipped into moulds. This cheese is more or less tasteless, since there is very little flavour to albumen, but it is very nutritious.

Ash.

The ash of milk is the part left after milk has been dried and burned, and contains the mineral matter of the milk. It is partly in suspension and partly in solution. The ash is the most constant constituent of milk and rarely goes below .68 or above .72 per cent.

Ash is important for growing animals because it contains material necessary for bone formation. Some of the minerals found in the ash of milk are salts of sodium, potassium, magnesium and phosphorus.

CREAM

Cream is milk in which a large percentage of fat has been collected. The increase in percentage of fat means, of course, a corresponding decrease in the percentage of the other milk constituents. The New York State dairy laws specify that market cream shall contain not less than 18 per cent. of fat. Often the percentage of fat is much higher, and when cream is shipped it is sometimes made to contain as high as 50 or 60 per cent. of fat in order to save transportation rates.

Fleischman gives the composition of cream having high and low percentages of fat as follows :—

	Percentage	
	Cream high in fat.	Cream low in fat.
Water	29.0	76.6
Fat	67.5	15.2
Casein Albumen	1.2	3.1
Sugar	2.2	4.5
Ash	.1	.6

The principal uses of cream are in the manufacture of butter and for market purposes. Cream is a good food, but it is usually regarded as an expensive food. For example, comparing cream at 40 cents per quart with whole milk at 8 cents per quart, it will be seen that five quarts of milk can be purchased for 40 cents, the price paid for one quart of cream. The food value of the five quarts of milk exceeds many times the food value of the one quart of cream.

There are two ways of separating cream from milk, the gravity and centrifugal methods. In the first method the milk is allowed to stand for several hours, and the fat, being lighter than the rest of the milk, rises to the top ; the cream is then skimmed off, or the skimmed milk is removed through a faucet in the bottom of the tank in which the milk is contained. In the second method the cream is extracted in a separator by means of centrifugal force. The milk is allowed to flow into the rapidly revolving bowl of the separator, and the fat, being lighter than the rest of the milk, is forced toward the centre of the bowl. As the revolving bowl becomes filled with milk the cream is forced out through the proper channel.

The statement has been made that separator cream is not so easily digested as is cream raised by gravity. The reason given for this is that the emulsion of fat is broken up by the separator. The truth of this statement has never been proved, and it is quite likely that separator cream is just as easily digested as is cream obtained by the gravity process.

SKIMMED MILK

Skimmed milk, or milk serum, is milk from which the fat has been removed. No process of separation is entirely complete and so a small percentage of fat remains in the skimmed milk. In skimmed milk from the separator the percentage of fat is very small, the aim of creamerymen being to get an average of not over .04 to .05 per cent. Small hand separators do not usually skim so closely as do large factory separators, but any separator should skim below .1 per cent. fat.

The following table shows the percentage composition of skimmed milk from the separator :—

	Percentage.
Water	90.60
Fat	.10
Sugar	4.95
Casein	3.15
Albumen	.42
Ash	.78

The food value of skimmed milk is not always appreciated. By referring to the above table it will be seen that skimmed milk is rich in proteids (casein and albumen), which makes it a valuable food, especially for growing animals.

BUTTERMILK

Buttermilk is the material left after churning butter from cream. Its contents depends somewhat on the percentage of fat lost during the process of churning, and frequently it is diluted with the water in which the butter is washed.

Richmond, quoting from Storch, gives the following percentage composition of buttermilk :—

	Percentage.
Water	90.93
Fat	.31
Sugar	4.58
Proteids (casein and albumen) ..	3.37
Ash	.81

The percentage of fat given is higher than it should be if the process of churning is properly carried out.

It may be seen from the table that buttermilk has a higher food value ; but it is especially valued as a food for the lactic acid that it contains. The amount of lactic acid in buttermilk varies, but is about .5 to .6 per cent. This acid is thought to have a stimulating effect on the digestive tract. The lactic-acid bacteria are said to overcome the putrefactive types and thus prevent putrefaction in the stomach and intestines.

WHEY

Whey is the fluid part of the milk that remains after cheese-making. It contains those ingredients of milk that are soluble—sugar, albumen, and part of the ash—and also more or less of the fat that escapes during the process of manufacture.

Van Slyke gives the following composition of whey :—

	Percentage.
Water	93.04
Fat	.36
Proteids (chiefly albumen) ..	.84
Sugar and salts	5.76

Whey is used chiefly as a food for animals. It is also used to some extent in modifying milk for infants and invalids. Containing, as it does, a high percentage of sugar and albumen, it is valuable in milk modification when the aim is to increase these constituents in the product.

QUESTIONS.

1. Describe milk and give a table showing its constituents, together with the approximate percentage of each.
2. Make out a table which classifies the constituents of milk as total solids, solids not fat, and whey.
3. Define amphoteric, density of milk, colostrum.
4. Discuss colostrum in relation to composition, use, human consumption.
5. Write a short note on milk fat, casein, milk sugar, albumen and ash, pointing out, as far as possible, importance, uses, form, properties, etc.
6. Give conditions affecting the percentage of butter fat found in milk.
7. What is cream ? What is it used for ? How do we get it ?
8. Discuss skimmilk, buttermilk and whey with respect to their value as foods.
9. " The number of dairy cattle is increasing much more rapidly than beef cattle." Why is this so ?
10. What further opportunities lie before a man who goes into dairying, in the way of opening up new markets for his dairy products in Canada ?